ILLINOIS NATURAL HISTORY SURVEY
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Multi-state Spatial Database to Assess Threats to Mussels

Final Performance Report 2012

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Background

Freshwater mussels are one of the most imperiled fauna in North America; approximately 70% of the 297 species within this group are considered endangered, threatened or of special concern. In the Upper Midwest (Region 3), seventeen mussels are listed as federally endangered or threatened, five are candidates for listing, and two are federal species of concern. Numerous others are on state threatened and endangered lists. These species are experiencing significant declines in both distribution and abundance, and the viability of these small and isolated populations is doubtful without intervention.

Mussels are sessile organisms without the ability to quickly retreat from threats, so they depend on the water quality and habitat conditions of their immediate environment to support them and their host fish populations. Widespread habitat degradation (e.g. pollution, channelization, siltation, dams and impoundments) is the primary cause of the declines observed over the last century. Siltation from poor agricultural practices and chemical contaminants from point (i.e. ammonia and metals) and non-point sources (i.e. pesticides and fertilizers), for example, are major threats to many of the mussel species in the Upper Midwest Region. Acute spills may directly kill mussels while chronic exposure to chemical contaminants can reduce population size by inhibiting growth and long term reproductive success. Habitat destruction is confounded by the rapid expansion of exotic invasive species populations that compete with native mussels for food and space. Eurasian zebra mussels (*Dreissena polymorpha*), for example, have been spreading throughout the Mississippi River basin since the early 1990s, and are quickly invading remaining native mussel refugia. Environmental degradation and invasive species invasions threaten numerous freshwater mussels with extinction throughout the Upper Midwest.

Comprehensively being able to spatially display threats that exist throughout the region will help direct freshwater mussel protection and restoration efforts, greatly reducing the extinction risk for these species. This project will focus on the following eight listed mussel species in USFWS Region 3 which includes (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin):

- Clubshell (*Pleurobema clava*)
- Curtis' Pearlymussel (*Epioblasma florentina curtisi*)
- Higgins Eye Pearlymussel (*Lampsilis higginsii*)
- Northern Riffleshell (*Epioblasma torulosa rangiana*)
- Purple Cat's Paw Pearlymussel (*Epioblasma obliquata obliquata*)
- Scaleshell (*Leptodea leptodon*)
- White Cat's Paw Pearlymussel (*Epioblasma obliquata perobliqua*)
- Winged Mapleleaf (*Quadrula fragosa*)

The objectives of this project are (1) to create a GIS database of locations of these eight listed mussel species within USFWS Region 3; (2) to make available a GIS database of water quality information and threats that may be relevant to listed mussels; (3) to use GIS tools to identify where threats may be impacting mussels; and (4) to provide field biologists access to all of the data and analysis tools developed in an easy to use format.

Data Layers, Methods, and Issues

Mussel Locations

An attempt to get data agreements in place with each of the eight states National Heritage Programs so this data can be used for the project was done by the USFWS. In the meantime, museum collection data as well as data from other sources (if any) was gathered by Illinois Natural History Survey (INHS) staff. Point locations for the entire range of each of the species was gathered even though the project area only covers USFWS Region 3, as it will be beneficial to the INHS and future projects if data is available for an entire species range.

Currently INHS uses FileMaker Pro software to store and manage various collections databases, so the database will be created and stored in FileMaker Pro and then exported so that a GIS layer can be created for the project. Once data from the a few museum collections and a few of the National Heritage Programs were obtained the data was evaluated and a list fields was determined so that a regional database with a consistent data structure could be built for use on the project. The fields included in the final mussel locations layer with an explanation of each are listed in Table 1.

Table 1. List of fields included in the final mussel locations layer.

Field Name	Description
Museum	Institution in which the specimens (if present) reside. Data from 19 different sources were collected for the project
CatalogueNo	The catalogue or reference number associated with the specimens for a particular museum
OriginalMuseum	This only refers to the University of Illinois Museum of Natural History (UIMNH) collection, which was transferred to the INHS
UIMNHCatalogNo	The catalogue or reference number associated with the University of Illinois Collection
Family	Mussel family name
Genus	Mussel genus name
Species	Mussel species name
Subspecies	Mussel subspecies name
Genus Species	A concatenation of genus, species, and subspecies fields
Original Name	Name as it appeared in a collection or database, typically a synonym
CommonName	The common name of the species
SpecificAuthority	Author of the scientific name
State	The state where the species is located

Field Name	Description
County1	The county where the species is located
County2	The second county, if located one or near the edge, where the species is located
Stream	Body of water where the species was located
Drainage	The larger unit of water to which the actual stream or lake flows into
NoVouchered	The number of specimens physically present in the collection (this can be different from the number observed in the field)
D	Indicates the number of dead shells. An x means that dead shells were found but the number of specimens was not recorded
L	Indicates the number of live specimens. An x means that the number of specimens was not recorded
R	Indicates the number of relict shells. An x means that the number of specimens was not recorded
SP	Indicates the number of soft parts preserved in the collection. An x means that the number of specimens was not recorded
CommonLocation	A common description of the location
Collection	Typically a private collection later donated to a museum
Collectors	Collector(s) of the specimen
YearRange	The year or range of years the specimen was collected
Year	The year the specimen was collect or earliest year if only a range was listed
Month	The month, if listed, the specimen was collected
Day	The day, if listed, the specimen was collected
OriginalDetermination	The person who identified the specimen
ReceivedFrom	The person who donated the specimen
LatLongSource	The person who determined the source of the latitude and longitude coordinates
Remarks	A general remarks field that contains various types of data or comments
LastObserved	Data from some of the heritage databases on the last observed occurrence of the species
CountyCode	A code used in the INHS collection to track unique collection sites within a given county

Field Name	Description
Lat_Long	Latitude and longitude coordinates indicated in the same field
Lat	The latitude, or north-south position, of the specimen
Long	The longitude, or east-west position, of the specimen
RiverMile	Mississippi or Ohio River mile as designated by the US Army Corp of Engineers or the USGS
SiteNumber	A site number given by the collector
QuadName	USGS 7.5-minute topographic quadrangle name
TRS	The Public Land Survey System (PLSS) Township, Range, and Section information
SpecimenRemarks	A remarks field for a specific specimen that contains various types of data or comments

Once the data was obtained from each source it was then parsed to conform to list of fields identified in Table 1 above. Latitiude and longitude coordinates were generated for those records only listing a common location using the NGA GEOnet Names Server (GNS) database (http://earth-info.nga.mil/gns/html/index.html) and ACME Mapper (http://mapper.acme.com/). Museum records regarded as spurious were discarded and mussel condition (live, dead, and relict) was noted if possible. In many cases it was not possible to tell whether or not the mussels in question were collected alive or represented old shells. Once the data from all sources was parsed, the final data with all mussel locations was exported out of FileMaker Pro as Excel 2010. Records which still contain no latitude and longitude information were removed, since they can't be used for the project. The excel file was then saved back to an Excel Workbook 1997-2003 format so that is can be read by ArcGIS. The excel file was added to ArcMap and all locations were plotted using the File --- Add Data --- Add XY data tool. Points were inspected for outliers or incorrect locations, and corrected if necessary. The data was then re-projected from Geographic Coordinate System (GCS) to USA Albers Equal Area Conic USGS projection, which is the chosen projection for the project as areas are proportional and directions are true in limited areas. This projection is good for regional and US wide datasets and is widely used by the US Geological Survey and US Census Bureau.

The mussel points were then snapped to the National Hydrography Dataset (NHD) flowline streams using ArcGIS processing tools, as this layer is the primary base layer used in the GIS tool, so it is important that the mussel locations fall directly on the streams. A number of different tools and commands were evaluated to snap the points to line (i.e. Hawth's tools, Near, etc), but some only worked in earlier versions of ArcGIS or numerous steps were needed to get to the final output. The RTWTools for ArcGIS toolbox was downloaded from https://github.com/robintw/RTWToolsForArcGIS, which includes a Python script incorporated into an ArcGIS Toolbox. This was the choice tool used for the project and is included with the data deliverables. This Python script uses the Near tool, located under Analysis Tools – Proximity in ArcToolbox, but also incorporates the necessary code to create a new point layer using the NEAR_X and NEAR_Y fields generated by the Near command. A feature class containing all original mussel locations, a feature class containing all mussel locations snapped to the NHD flowline, and eight

features classes each containing a single mussel species snapped to the NHD flowline are included in the final deliverable geodatabase.

By the end of the project only Natural Heritage data and agreements for Illinois, Indiana, Iowa, Missouri, Ohio, and Wisconsin were obtained, as this project doesn't currently fit under the current agreement expectation for Michigan and data for Minnesota was unable to be obtained in time for use on this project. Data from 12 different museum collections make up the majority of the point locations used for the project, but National Heritage data from 6 states as well as Higgin's Eye re-location data from the US Army Corps of Engineers project along the Mississippi River were combined to create a regional database with consistent data structure (Table 2).

Table 2. Data sources used for mussel locations

Data Source	Description
ANSP	Academy of Natural Science of Philadelphia
CHAS	Chicago Academy of Science
CM	Carnegie Museum
FMNH	Field Museum of Natural History Chicago
IA Heritage	Data obtained from the Iowa Natural Heritage collections
IL Heritage	Data obtained from the Illinois Natural Heritage collections
IN Heritage	Data obtained from the Indiana Natural Heritage collections
INHS	Illinois Natural History Survey
INSM	Indiana State Museum
ISM	Illinois State Museum
MCZ	Museum of Comparative Zoology, Harvard University
MO Heritage	Data obtained from the Missouri Natural Heritage collections
Not Saved	Unknown collection
OH Heritage	Data obtained from the Ohio Natural Heritage collections
OSUM	Ohio State University Museum of Zoology
UMMZ	University of Michigan Museum of Zoology
USACE MCT	Higgins Eye re-location project data along the Mississippi River
USNM	United States National Museum
WI Heritage	Data obtained from the Wisconsin Natural Heritage collections

The final USFWS Region 3 mussel database contains a total of 3,247 records with a breakdown of the following:

- Clubshell (*Pleurobema clava*) – 1,580 records
- Curtis' Pearlymussel (*Epioblasma florentina curtisi*) – 80 records
- Higgins Eye Pearlymussel (*Lampsilis higginsii*) – 595 records
- Northern Riffleshell (*Epioblasma torulosa rangiana*) – 499 records
- Purple Cat's Paw Pearlymussel (*Epioblasma obliquata obliquata*) – 43 records
- Scaleshell (*Leptodea leptodon*) – 303 records

- White Cat's paw Pearlymussel (*Epioblasma obliquata perobliqua*) – 74 records
- Winged Mapleleaf (*Quadrula fragosa*) – 73 records

NOTE: Data from all sources were kept, however there may be duplicate point locations obtained from the various state Natural Heritage programs and the museum collection data as many of the museum records were sent to the various state Natural Heritage Programs once they were collected.

Base Data Layers and Tools

The **USA Base Map** layer file (USA Base Map.lyr) from ESRI Data and Maps 10 is used as a background data layer in the final ArcMap document named *USFWSMusselsThreats_10_1.mxd.* This layer file as well as associated data layers is included in the final deliverables.

The **USFWS Region Boundaries** file was downloaded from http://www.fws.gov/gis/data/national/index.html. USFWS Region 3, which is the study area for the project, was selected and exported as a feature class and is included in the final geodatabase. The USFWS Region 3 layer was buffered by 10 miles and saved as an additional feature class. This buffered layer was used to clip the mussel locations and various "threats" data layers to ensure capturing enough of the "extra" data needed.

The 1:24,000-scale, high resolution, **National Hydrography Dataset (NHD),** specifically the NHDFlowline, is the main base data layer that is used for the mussel threats tool. The NHD is stored in a file geodatabase and is organized into several forms of geometry and into several supporting tables. The geodatabase contains two Feature Datasets of geometry. The Hydrography feature dataset contains the NHD whereas the Hydrographic Units feature dataset contains the Watershed Boundary Dataset (WBD). These data are designed to be used in general mapping and in the analysis of surface-water systems.

The Hydrography feature dataset contains eight forms of geometry known as Feature Classes.

- *NHDFlowline* – this is the fundamental flow network consisting predominantly of stream/river and artificial path vector features. It represents the spatial geometry, carries the attributes, models the water flow, and contains linear referencing measures for locating events on the network. Additional NHDFlowline features are canal/ditch, pipeline, connector, underground conduit, and coastline.
- *NHDLine* - contains linear features not core to the network,
- *NHDPoint* - contains hydrography related point features
- *NHDWaterbody* - basic waterbodies such as lake/pond features are represented here. They portray the spatial geometry and the attributes of the feature. These water polygons may contain NHDFlowline artificial paths to allow the representation of water flow. Other NHDWaterbody features are swamp/marsh, reservoir, playa, estuary, and ice mass.
- *NHDArea* - contains many additional features of water polygons. One of the more important is the stream/river feature. It represents the aerial extent of the water in a wide stream/river with a basic set of attributes. They typically contain NHDFlowline artificial paths that are used to model the stream/river. Artificial path carries the critical attributes of the stream/river, whereas NHDArea represents the geometric extent.
- *NHDPointEventFC, NHDLineEventFC, and NHDAreaEventFC* - represent point, line, and area data events that behave as map features and linearly referenced events. Streamgages, which are

point features, can be displayed and identified in the network through linear referencing with a network address.

Also contained in the Hydrography feature dataset, are *HYDRO_NET* geometric network and related point feature class *HYDRO_NET_Junctions*. These layers are created when the network is built from the NHDFlowline feature layers. This can be done using ArcCatalog. When the new network is built, if there are errors, these are written to an error table named *HYDRO_BUILDERR*. If the network needs to be rebuilt, the HYDRO_NET geometric network, HYDRO_NET_Junctions point feature class, and the Object table HYDRO_NET_BUILDERR all need to be deleted before the rebuild

The WBD feature dataset contains eight feature classes. Each feature class represents a hydrologic unit level in increments of two, with the largest areas being *WBD_HU2* and the smallest areas being *WBD_HU16*. The hydrologic unit is a drainage area delineated to nest in a multi-level, hierarchical drainage system. Its boundaries are defined by hydrographic and topographic criteria that delineate an area of land upstream from a specific point on a river, stream or similar surface waters.

Information about the NHD also can be obtained in a series of associated tables. This includes metadata stored in *NHDFeaturetoMetadata* and *NHDMetadata*, sources given in *NHDSourceCitation*, identification of model and data version given in *NHDProcessingParameters*, flow relations given in *NHDFlow*, reach code histories given in *NHDReachCrossReference*, the domain of feature codes given in *NHDFCode*, and others.

The largest area for which the NHD data can be downloaded is at the state level, so the latest statewide high resolution NHD data was downloaded for each of the eight states in USFWS Region 3 from ftp://nhdftp.usgs.gov/DataSets/Staged/States/FileGDB/HighResolution/. In order to create custom functionality for the USFWS Mussel Threats tool, a single seamless regional geodatabase containing all the NHD and WBD layers is needed. The process of merging together all eight states to create single geodatabase, re-project this geodatabase from Geographic Coordinate System (GCS) to USA Albers Equal Area Conic USGS, and then re-build the geometric network was a much larger task than originally anticipated. We ran into many technical difficulties and tried numerous tools using three different versions of ArcGIS software (version 9.3.1, 10.0, and 10.1). The method and tools which finally worked is discussed below.

The **USFS Reprojection Tool Version 2.0** was downloaded from http://nhd.usgs.gov/tools.html. The USFS Reprojection Toolbar changes geographic projection and can transform datums using all available ESRI ArcObjects algorithms. It was developed by the USDA-Forest Service for the National Hydrography Dataset (NHD) NHDinGEO format, but can function on any personal or file geodatabase. This is an add-on toolbar written for ESRI's ArcGIS 9.2, 9.3, and 10 and is used in ArcCatalog. The advantage is that it re-projects whole personal and file geodatabases at once, and updates the metadata at both the Geodatabase, Dataset, and Feature class levels in both the Data Quality and Spatial Reference sections of standard FGDC metadata--or creates its own metadata if there is none. Version 2.0 works on ArcGIS 9.2 while version 2.1 works on ArcGIS 9.3, 2.2 works on ArcGIS 10. This was the only tool that worked to re-project the entire NHD geodatabase from Geographic Coordinate System (GCS) to USA Albers Equal Area Conic USGS, but it only seems to work in ArcGIS 10.0 so this is the version of the software which was used to completed the final geodatabase for the project.

A toolbox which calls a python script, created from a previous project, was provided by Erik Olson at the USFWS. This python script appends NHDFlowline classes from multiple geodatabases for use in a network. Because NHD databases are often served in smaller sets than may be needed for a regional project, the datasets often have some overlapping features when combined for a large project. This tool combines them without duplication. Python scripts for each of the feature classes in the NHD geodatabase were created and a toolbox with all toolbox tools used, called **NHD_tools.tbx**, is included in the final deliverables.

Arc Hydro Tools Version 2.0 was downloaded from http://blogs.esri.com/esri/arcgis/2011/10/12/arc-hydro-tools-version-2-0-are-now-available/. Arc Hydro is a set of data models and tools that operates within ArcGIS to support geospatial and temporal data analyses. Arc Hydro is used to delineate and characterize watersheds in raster and vector formats, define and analyze hydro geometric networks, manage time series data, and configure and export data to numerical models. The Arc Hydro toolbar contains many choices with many functions. For the creation and manipulation of the datasets for this project only a few of the functions were used. Since of most of the Arc Hydro functionality is beyond the scope of this document if the user wants to further explore the uses of Arc Hydro, it is recommended to search online for a variety of documentation, tutorials, and exercises.

Re-projecting each of the eight state NHD geodatabases from GCS to Albers, and then running the append python scripts on the Albers geodatabase was tried first. All seemed to go fine, except when we tried to re-create the geometric network on the Albers regional NHDFlowline layer, ArcMap seemed to always hang up and it would not create the geometrics network. Thus, the reverse of running the python scripts to append each of the eight states together in GCS, and then re-projecting the regional geodatabase from GCS to Albers was tried. This seemed to be the method which worked best; however only a few states could be appended together at a time otherwise we would get errors when rebuilding the geometric network. Thus, the regional database needed to be completed in two steps, using four states at a time, rather than all in one step. The Append tool, followed by the Delete Identical, located under Data Management Tools --- General -- in ArcToolbox, was used to combine all the geodatabase tables into the regional NHD geodatabase. Once the regional NHD geodatabase containing feature classes and tables from all layers was completed, the USFS Reprojection Toolbar was used to re-project the regional geodatabase from Geographic Coordinate System (GCS) to USA Albers Equal Area Conic USGS. The geometric network was then created in ArcCatalog with no issues. Set Flow Direction, located under the Network Tools in the Arc Hydro toolbar was then used to set the flow direction of the NHDFlowlines for use with the USFWS Mussel Threats tool.

Threats Layers

An initial list of potential threats to mussels was identified and includes the following:

- Dams and Impoundments
- Channelization
- Siltation from poor agricultural practices
- Leaking Underground Storage Tanks (LUST)
- Chemicals/Non-Point Source Pollutants
    - Pesticides
    - Fertilizers
    - Ammonia
    - Nitrogen

    - Phosphorus
- Heavy Metals/Point Source Pollutants
    - Copper
    - Cadmium
- Water Quality Data
    - 303(d) listed impaired waters
    - NAWQA
    - 2009 Beach NHD Indexed
    - 2002 impaired waters baseline data

The United States Environmental Protection Agency (USEPA) and the United States Geologic Survey (USGS) have been identified as the main sources of data, with some covering the entire USFWS Region 3 area, while other layers, like LUST, pesticides, and the chemicals have been identified for most but not all states. Many of the statewide datasets need to be extracted and it seems like lots of editing is needed to get it into a usable format for use on this project. Since we were having lots of technical issues trying to get the NHD streams data completed, which is the base data layer used in the mussel threats tool, less time was available to gather and edit threats data layers for the project. Since one of the objectives of the project is to develop a GIS tool to identify where threats maybe be impacting mussels we have decided to focus on using five different threats layer (these are mainly USEPA datasets) which cover the entire USFWS Region 3 area, and design the tool so that the user can add additional threats data at any time. The five threats layers that are included with the final mussel geodatabase include NHD Dams, US EPA Toxic Release Inventory (TRI) sites, US EPA 303(d) impaired waters, US EPA ICIS Facilities, and US EPA ICIS Outfalls and are discussed in more detail below.

Data for **Dams** was downloaded from National Atlas (http://nationalatlas.gov/) as well as from the USGS NHD data (http://nhd.usgs.gov/data.html). The feature class called NHDPointEventFC contains information for Dams, as well as Gaging and Water Quality Stations from the USGS. The data from both these sources was very similar, but since we are already using the NHD data as the base layer for the tool, we decided to just go ahead and use the USGS NHDPointEventFC for the Dams layer. The only editing this data needed, was to extract out only the Dams from this layer and save it as a separate layer, called NHD_Dams.

Toxics Release Inventory (TRI) data is published annual by the US EPA which contains pertinent information about locations of toxic chemical releases. TRI data for reporting year 2010, was downloaded from http://www.epa.gov/tri/tridata/data/basicplus/index.html. The file is a zipped file (US_2010_v10.zip) and when unzipped, contains seven text files. These files are tab-delimited with the first row being the header row. There are about 208 fields, most of which aren't needed. All the fields were initially created as text fields, and by default, have a length of 255 characters, which is way more than is needed for many of the fields. The data was imported into an Excel file and saved as Excel Workbook 1997-2003 format so that is can be read by ArcGIS. The excel file was added to ArcMap 10.1 and all locations were plotted using the File --- Add Data --- Add XY data tool. The data was exported and saved as a shapefile and then re-projected from Geographic Coordinate System (GCS) to USA Albers Equal Area Conic USGS. Due to limitations of the GIS shapefile format (shapefiles are used as the export format when the reports are generated from the USFWS Mussel Threats tool), the total record length needed to be restricted to 4,000 bytes and because of this, a number of fields needed to be deleted before the layer was created. In order to create a good report,

the TRI attribute fields were edited from the original data layer and are listed in Table 3. The field names are limited to 10 characters, so some of the field names needed to be edited because they first share these first 10 characters in common.

Table 3. List of original and final edited names in the final TRI2010 data layer

Original Name	Edited Name
FACILITY_NAME	FAC_NAME
FACILITY_STREET	FAC_STREET
FACILITY_CITY	FAC_CITY
FACILITY_COUNTY	FAC_COUNTY
FACILITY_STATE	FAC_STATE
FACILITY_ZIP_CODE	FAC_ZIPCOD
ENTIRE_FACILITY_IND	EN_FAC_IND
PARTIAL_FACILITY_IND	PARTFACIND
FEDERAL_FACILITY_IND	FEDFAC_IND
GOCO_FACILITY_IND	GOCO_IND
PRIMARY_SIC_CODE	PRI_SIC_CO
PUBLIC_CONTACT_NAME	PUB_NAME
PUBLIC_CONTACT_PHONE	PUB_PHONE
PRIMARY_NAICS_CODE	PRI_NAICS
NAICS_CODE_2	NAICS_2
NAICS_CODE_3	NAICS_3
NAICS_CODE_4	NAICS_4
NAICS_CODE_5	NAICS_5
NAICS_CODE_6	NAICS_6

The **US EPA 303(d) impaired waters** data identifies waters that are too polluted or otherwise degraded to meet the state water quality standards. This data was downloaded from http://www.epa.gov/waters/data/downloads.html#State and Watershed Geospatial Data. The downloaded data is a file geodatabase and the only layer used for this project is the rad_303_l feature class. The only editing this data needed, was to re-projected the data from Geographic Coordinate System (GCS) to USA Albers Equal Area Conic USGS.

The US EPA National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Data for permitted discharges as of April 2010, **US EPA ICIS Facilities and US EPA ICIS Outfalls**, was obtained from the US EPA Region 5. All states, except Iowa, have moved to the more recent Integrated Compliance Information System (ICIS) database for reporting, so two separate files were sent for each layer as the fields don't match exactly. Metadata was not included for these datasets, but can be found at http://water.epa.gov/scitech/datait/models/basins/pcs.cfm

The text field sizes in each of the data files needed to be edited to match exactly so they could be appended together in one file. In particular, the Iowa layer needed to have the NPDES text field sized up to 16 characters, the FACILITY_N (facility name) to 57 from 32, the STATUS from 6 to 15, and the field RECEIVING_ (receiving waters) field from 32 to 50 characters. The other layer, which includes the remains seven states in USFWS Region 3, needed the TYPE field changed from 8 characters to 10. Once these changes were complete, the two layers were appended together and re-projected from Geographic Coordinate System (GCS) to USA Albers Equal Area Conic USGS.

Time ran out on the project before we could gather all valuable threats data layers for this project. However, the GIS tool developed for the project was designed to be able to easy add additional threats data layers as needed. After discussions with mussel biologists at the USFWS Region 3 Federal/State T&E Coordinators meeting in October 2012, focus for future threats to mussels should include the following layers:

- Eurasian zebra mussels (*Dreissena polymorpha*) locations
- Dredging sites
- Fish host sites
- Superfund sites
- Sewage treatments plants
- In-stream gravel mining
- Ammonia and copper concentrations

Final Data and Mussel Threats Tool

The USFWS Mussel Threats tool and all final data are located in a folder called **MusselThreats**. This folder can be copied to any location on a desktop computer or network computer as long as an environment variable is set to the location of this folder, otherwise the tool will not work. Instructions for initial setup and use of the USFWS Mussel Threat tool can be found in Appendix A. The final data for the project is stored in a file geodatabase named **USFWS_Region3_MusselsDatabase_Albers10.gdb** and the Mussel Threat tool and data have been organized and symbolized in the ArcMap document named **USFWSMusselsThreats_10_1.mxd.**

The geographic extent of nearly all of the GIS layers has been clipped to the USFWS Region 3 layer, buffered by 10 miles. The GIS layers are grouped in the ArcMap table of contents (TOC) in a way that mirrors their grouping as feature datasets in the geodatabase for these layers: Mussels, Threats, and Rivers & Streams. The minimum scale was set to 1:200,000 for the Rivers & Streams layers, which includes the NHD Flowlines.

The Mussels group contains the eight freshwater mussel species listed as federally endangered in USFWS Region 3. There are feature classes for each separate species, snapped to the NHD Flowlines, and a feature class which contains all eight species together, snapped to the NHD Flowlines. The user is encouraged to create separate feature classes or shapefiles which contains a subset of the mussel points, in order to make the process quicker and more manageable. Additional locations from other sources can easily be added in the future by adding the layer in ArcMap and then moving that layer to the Mussels group.

The Threats group contains the following five threats layers gathered for the project, NHD Dams, US EPA Toxic Release Inventory (TRI) 2010, US EPA ICIS Facilities, US EPA ICIS Outfalls, and US

EPA 303(d) Impaired Waters. Each layer is clipped to the 10 mile buffer USFWS Region 3 polygon. Additional threats layers can also easily be added in the future by adding the layer in ArcMap and then moving that layer to the Threats group.

The Rivers & Streams group contains the NHD layers, which includes the NHDFlowlines and other water features consisting of point, line, polygon, and network features. Additional stream network layers can also easily be added in the future by adding the layer in ArcMap and then moving that layer to the Rivers and Streams group.

Throughout the course of the project, a number of tools, various GIS datasets, and even various versions of ArcGIS software were reviewed. Since the NHD is the base layer to be used in the mussel threat tool, and the most current geodatabases downloaded were for ArcGIS 9.3.1, first attempts were made to develop the tool using ArcGIS 9.3.1. It was also initially thought that for maximum backward-compatibility the best choice would be ArcGIS 9.3, as opposed to version 10.0 or 10.1. This version was quickly thrown out, because we didn't want to spend a lot of time customizing a tool using a combination of Python and Visual Basic for Applications (VBA) code, as VBA is already being retired by ESRI. There are also no native Utility Network Analyst geoprocessing tools available for programming. We then looked into using ArcGIS 10 as this is the version that were able to finally get the USFS Reprojection Tool Version 2 to work, which allowed us to merge and reproject the eight individual state NHD data into a seamless regional NHD streams database. ArcGIS 10 introduced a new and innovative way to customize and extend the ArcGIS Desktop applications, which is by using a Desktop add-in model. The new add-in model provides one with a declaratively-based framework for creating a collection of customizations conveniently packaged within a single compressed file. Add-ins are easily shared between users as they do not require installation programs or Component Object Model (COM) registration; they are added to a system by simply copying them to a well-known folder and removed by deleting them from this folder. Add-ins can also be shared between users within an organization using a centralized network share. Add-ins at ArcGIS 10 can only be authored using .NET or Java along with Extensible Markup Language (XML) and there are still no native Utility Network Analyst geoprocessing tools available for programming at this version, so it was also thrown out. In reviewing the Desktop Add-ins at ArcGIS 10.1, we learned that Python had been added to the list of languages for authoring Desktop Add-ins as well as the geoprocessing tools as native Python applications (Python script functionality) for the Utility Network Analyst. This means the frontend, which is the dialog box for selection of the NHDFlowline, mussels, and threats layers is being recreated natively in Python, so that Models and Python scripts can use these specific geoprocessing tools. Once that is done, the added advantage of using the NHDPlus 2.1 layers, including the raster GIS data layers, will provide much functionality and expandability so this project can be a stepping stone to the future, rather than being stuck in the past with version 9.3, or even 10.0.

This is an important point, because ArcGIS technology continues to evolve; specifically, using 10.1 will allow the custom geoprocessing tool to be published to the Web as a geoprocessing service using ArcGIS Server 10.1. This is not possible using ArcGIS 9.3 or 10.0 which incorporate VBA code. Though it appears that creating and publishing a geoprocessing tool is doable using VB.NET or C#, from a programming perspective the higher level language of Python is much easier to program, with fewer lines of code needed, and an application written in VB.NET or C# still would export variables and functionality to ModelBuilder, Python, and the Python geoprocessing tools which are compatible with the ModelBuilder.

This research of various tools in various versions took a considerable amount of time and the final decision to go with ArcGIS 10.1 wasn't made until August 2012, which only gave us a couple months to develop and complete the tool. It was well worth the time to thoroughly research the best options for the development of the tool, as once the tool is complete, this Python functionality will be more "future-proof" because it can be added to and expanded by the next developers and programmers in a relatively easy manner.

Python Notes

When Python is installed it should create the PYTHONPATH environment variable, but it doesn't always do so, and this may need to be set up manually. This path variable should include the path to your Python install folder (i.e. Python27), and also the path to the ArcGIS Python install (i.e. C:\ArcGIS\Desktop10.1\arcpy\). It appears the trailing slash might be needed, and is certainly allowed. It also doesn't hurt to put the Python executable path within the computer Path variable so that when installing extra Python modules, the command using the Python.exe file doesn't have to referenced by the entire path (i.e. "Python.exe" versus "C:\Python27\Python.exe").

Another helpful Python module which needs to be installed allows the use of message boxes, with the command msgbox(), where the parentheses contain the message to be displayed in a dialog box with a button used to dismiss the box. This Python module is named EasyGUI and is available at http://easygui.sourceforge.net/. Follow the instructions on the website to install, but make sure the install location is within the PYTHONPATH, or edit the path to include the install location.

Python Add-ins for ArcGIS Desktop 10.1

The tool uses the ESRI Python Add-In Wizard. In order to create and use an Add-In project in ArcMap 10.1, the Python Add-In Wizard needs to be downloaded and unzipped. This is available at http://www.arcgis.com/home/item.html?id=5f3aefe77f6b4f61ad3e4c62f30bff3b. The help file for this can be found at http://resources.arcgis.com/en/help/main/10.1/index.html#/What_is_a_Python_add_in/014p00000025000000/

The Python Add-In Wizard is launched from the AddInFiles directory, either by double-clicking on the shortcut named **addin_assistant_shortcut** (which assumes the MUSSELSTHREATS environment variable has been set), or by opening the bin subfolder and double-clicking on the **addin_assistant.exe** file. Click on the **Select Folder…** button and navigate to the AddIns folder, which in this example is located in C:\MusselsThreats\AddInFiles\AddIns. Clicking on the **Add-In Contents** tab shows the included extensions, menus, and toolbars (Figure 1).

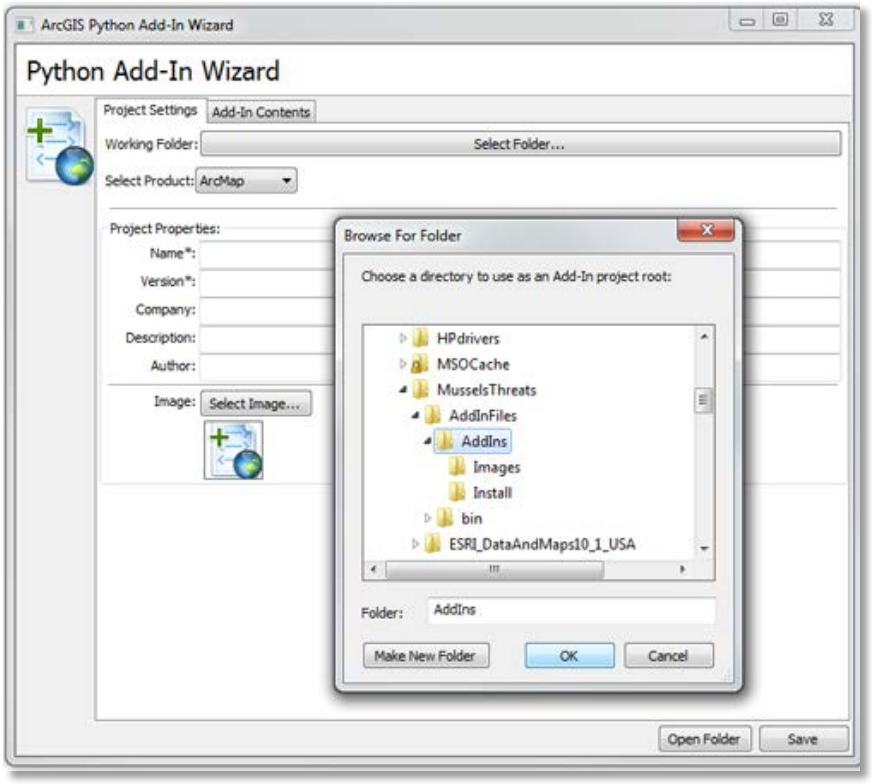

Figure 1. Python Add-In Wizard

Selecting the "Select Mussels" tool will list the name of the class in the Python code, which in this case is named ComboBoxMusselsClass (Figure 2).

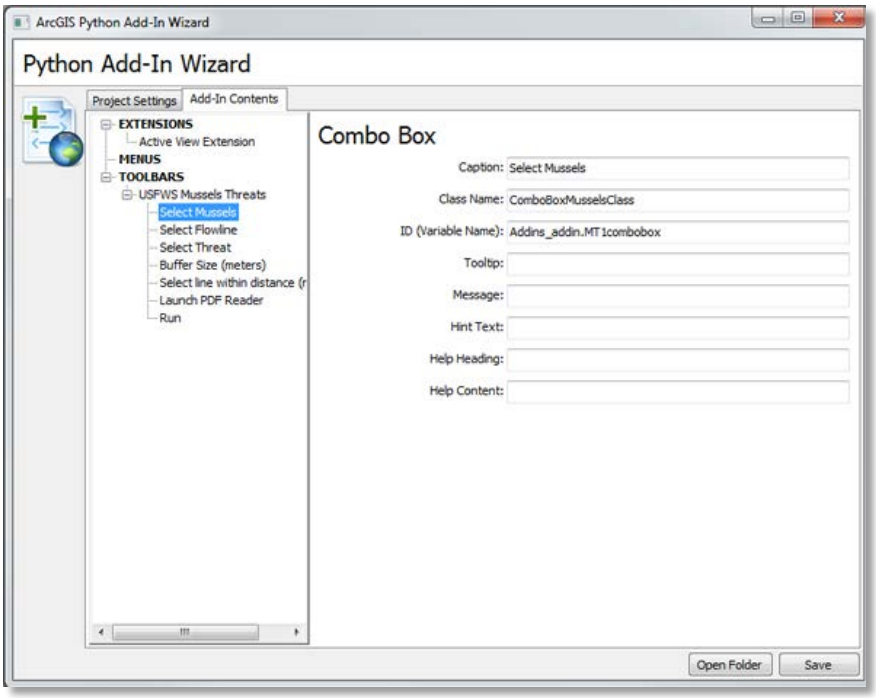

Figure 2. Mussel Threats Tool Components in the Python Add-In Wizard

Each of the classes has their own class as a block of code in the Python script. The script is saved in the **AddIns\Install** folder. The AddIns folder can be opened by clicking on the "Open Folder" button of the Python Add-In Wizard (Figure 3).

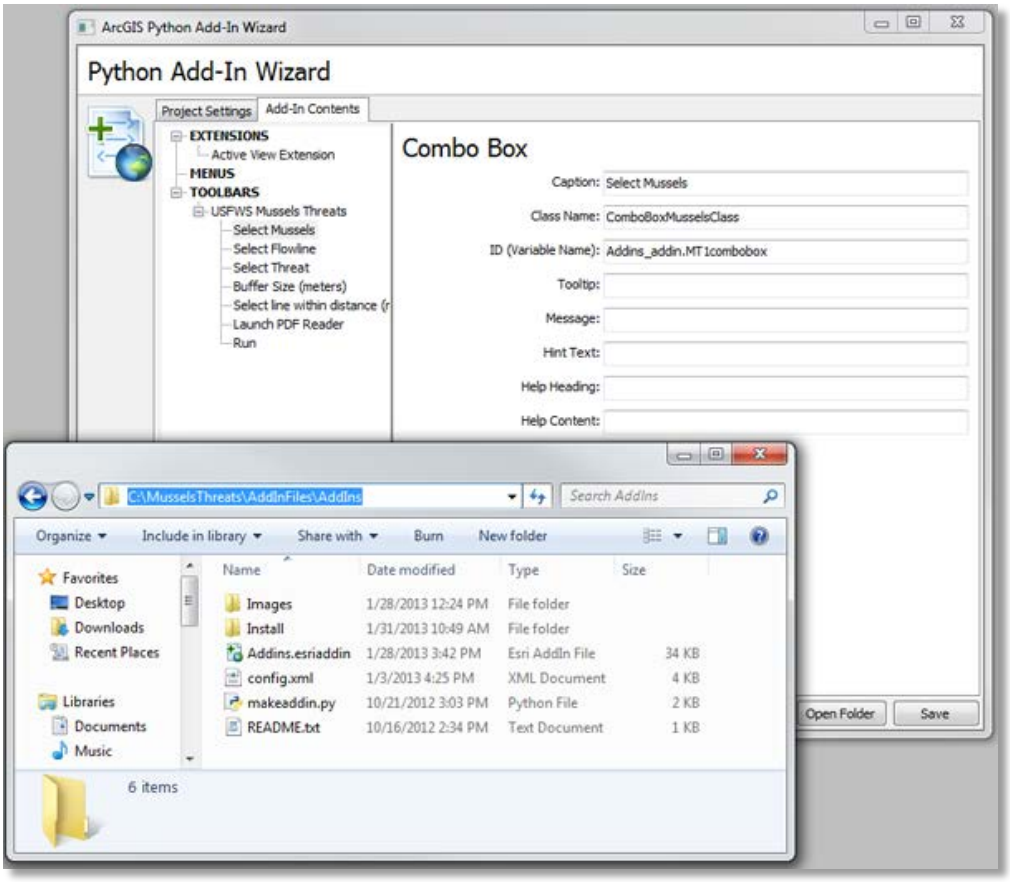

Figure 3. Python code for Mussel Threats Tool Components in the Python Add-In Wizard

Reports are created using ArcMap. From the menu bar, open View -> Reports, the choose Create or Load. When creating a new report, there are two formats for the tables in the report writer: stepped and outline. The stepped report groups by page, while the outline report shows alternately the field headings and the field records.

It does not matter where on the computer the files are kept to create the add-ins, however for this project all the files for the add-in can be found in the **MusselThreats\AddInFiles\AddIns** folder. Running the **makeaddin.py** file followed by the **Addins.esriaddin** creates the add-in in the Windows user's folder at C:\Users\<username>\AppData\Local\ESRI\Desktop10.1\AssemblyCache, as a key of length of 36 characters, for example, {5A5ED9A5-53AC-E681-6567-A921D95AC237}. The user who executes the Addins.esriaddin has the add-in automatically installed into the ArcMap extensions. If the add-in needs to be shared by a network share, the instructions can be found at http://resources.arcgis.com/en/help/main/10.1/index.html#//014p0000001m000000

Appendix A

User Manual for USFWS Mussels Threats Tool Version 1.0 for ArcMap 10.1

USFWS Mussels Threats Tool Functionality

The purpose of the USFWS Mussels Threats Tool version 1.0 is use GIS technology to investigate and report on possible threats to eight federally endangered mussel species. The tool runs in ESRI's ArcMap 10.1 with SP1, and uses a Python Add-In using version 2.7.2 to geographically select possible environmental threats to mussels, and then create tabular reports on these threats.

Though the tool is complete, it is also designed to allow future upgrades and expansion with both data and functionality. Additional GIS layers can be easily added to the ArcMap document (*.mxd file), especially new point location data and threat layers, and the tool will select on these layers as well as the previously existing layers. The default coordinate system is USA Contiguous Albers Equal Area Conic USGS. The Albers projection is a conic, equal area map projection that distorts scale and distance except along standard parallels. Areas are proportional and directions are true in limited areas. This projection is used by the United States (US Geological Survey, US Census Bureau, etc.) and other large countries with a larger east-west than north-south extent.

In order to fully use the USFWS Mussel Tool, ESRI's Utility Network Analyst Extension and the Hydrography Event Management (HEM) Tool is required. The Utility Network Analyst is for analysis on geometric networks and is used in conjunction with the National Hydrography Dataset (NHD), which is the base data layer used in the tool. The HEM Tool provides full functionality for adding and editing events in the NHD. Events are informational data that are linked to the NHD using a linear referencing system on NHDFlowlines. The use of events is a key characteristic of the NHD by allowing vast amounts of scientific information to be linked to the NHD while keeping the design simple and by making advanced analysis techniques possible. The HEM tool was developed by the Department of the Interior - Bureau of Land Management and can be downloaded from the USGS NHD website at http://nhd.usgs.gov/tools.html. Arc Hydro Tools for ArcGIS can also be used, but is not required. The latest version is Arc Hydro Tools for 10.1 BETA and can be downloaded for free from ESRI's ArcGIS Resources at http://blogs.esri.com/esri/arcgis/2012/11/26/are-you-using-arc-hydro-tools-for-10-1-beta. Arc Hydro is a set of data models and tools that operates within ArcGIS to support geospatial and temporal data analyses. Arc Hydro is used to delineate and characterize watersheds in raster and vector formats, define and analyze hydro geometric networks, manage time series data, and configure and export data to numerical models.

Initial Set-up

One Environment Variable needs to be set manually in the Windows operating system (ArcMap only works in Windows) in order for the Mussel tool to work. This variable contains the path to the directory where the MusselsThreats database and associated files is located. Environment Variables are set in the System Control Panel, and can be accessed by right-clicking on the **Computer** (or My Computer) icon, selecting **Properties**, then selecting **Advanced System Settings** to open the **System Properties** dialog box, selecting the **Advanced tab**, and clicking the **Environment Variables…** button.

The dialog for Environment Variables opens, and then the second **New…** button should be clicked. The four steps are labeled in Figure 1.

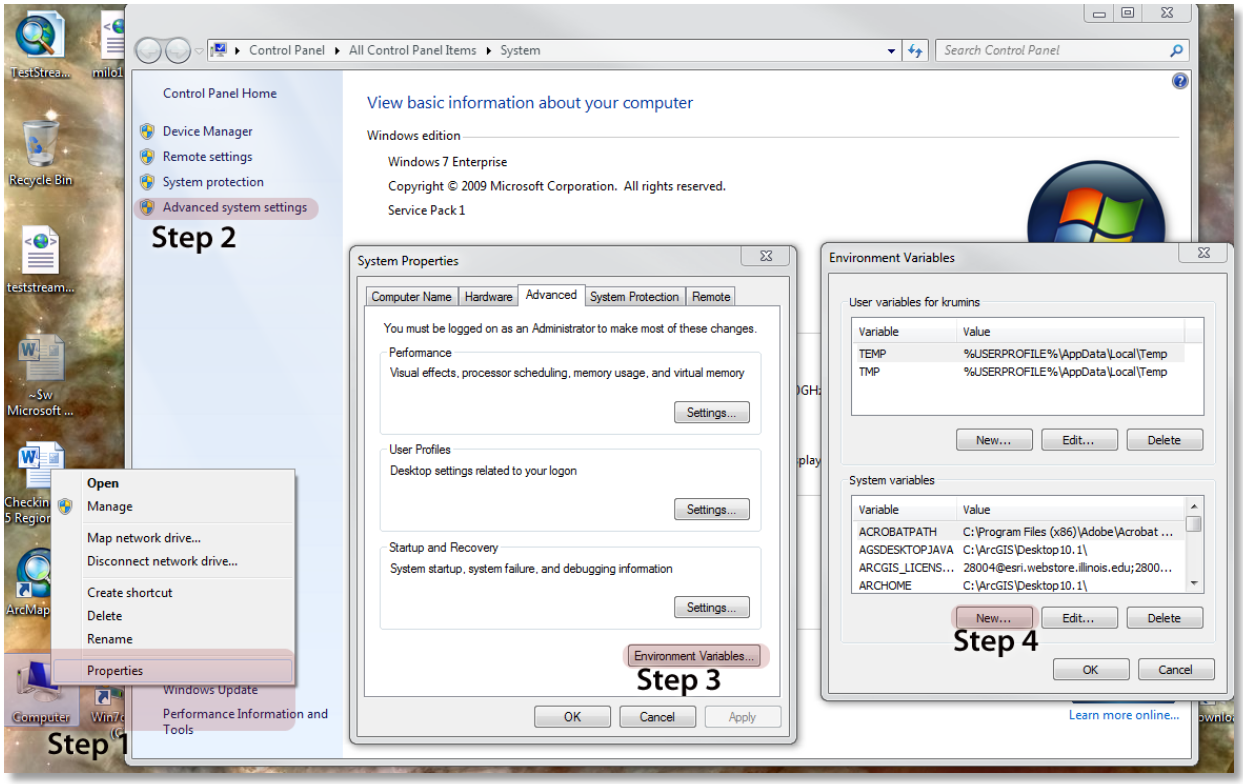

Figure 1. Setting the environment variable

Once the **New…** button is clicked, the **New System Variable** dialog appears. Set the **Variable Name** to **MUSSELSTHREATS** (this is the name of the environment variable as referenced in the tool and must always be set to this text string). Then set the **Variable Value** to the location of the home directory where the MusselsThreats data that was delivered for the project is located. In this example, the location has been set to **C:\MusselsThreats** (Figure 2). Then click OK three times to close the last three dialog boxes.

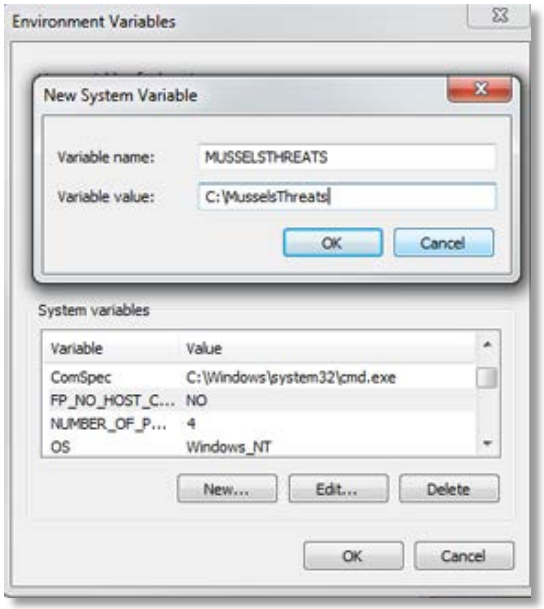

Figure 2. Creating a new environment variable

Installing the USFWS Mussel Threats Python Add-In

Open the ArcMap document named ***USFWSMusselsThreats_10_1.mxd*** in the home directory (the same one as set in the MUSSELSTHREATS environment variable).

Select **Add-In Manager** from the **Customize** Menu (Figure 3) to open the Add-In Manager dialog box (Figure 4).

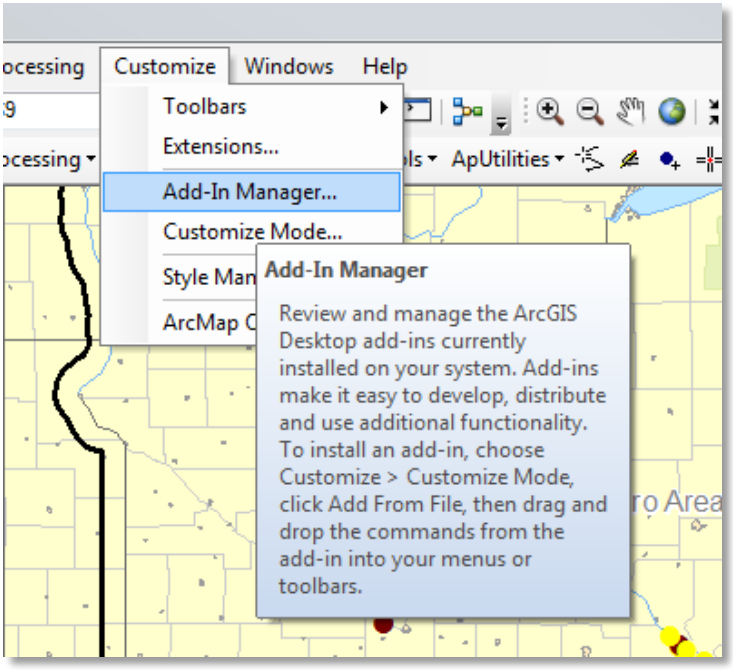
Customize
Windows
Help
Toolbars
Extensions...
Add-In Manager...
Customize Mode...
ApUtilities
Add-In Manager
Review and manage the ArcGIS Desktop add-ins currently installed on your system. Add-ins make it easy to develop, distribute and use additional functionality. To install an add-in, choose Customize > Customize Mode, click Add From File, then drag and drop the commands from the add-in into your menus or toolbars.

Figure 3. Locating the Add-In Manager

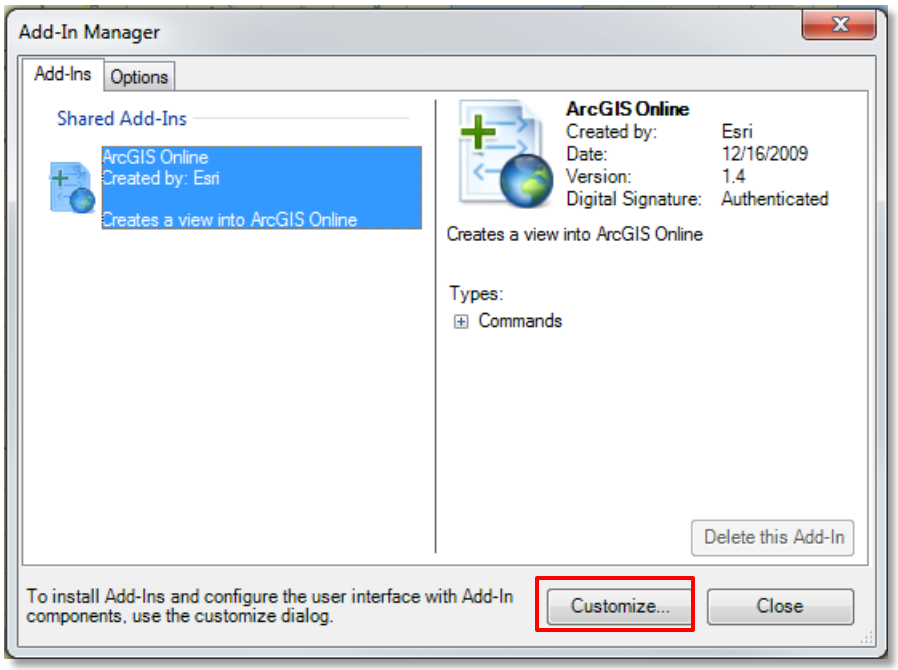

Figure 4. Add-In Manager dialog box

Click the **Customize** button to open the Customize dialog box and then click on the **Add From File** button. Navigate to the **Addins.esriaddin** file which is located in the MusselThreats home directory under AddInFiles\AddIns and select **Open** (Figure 5).

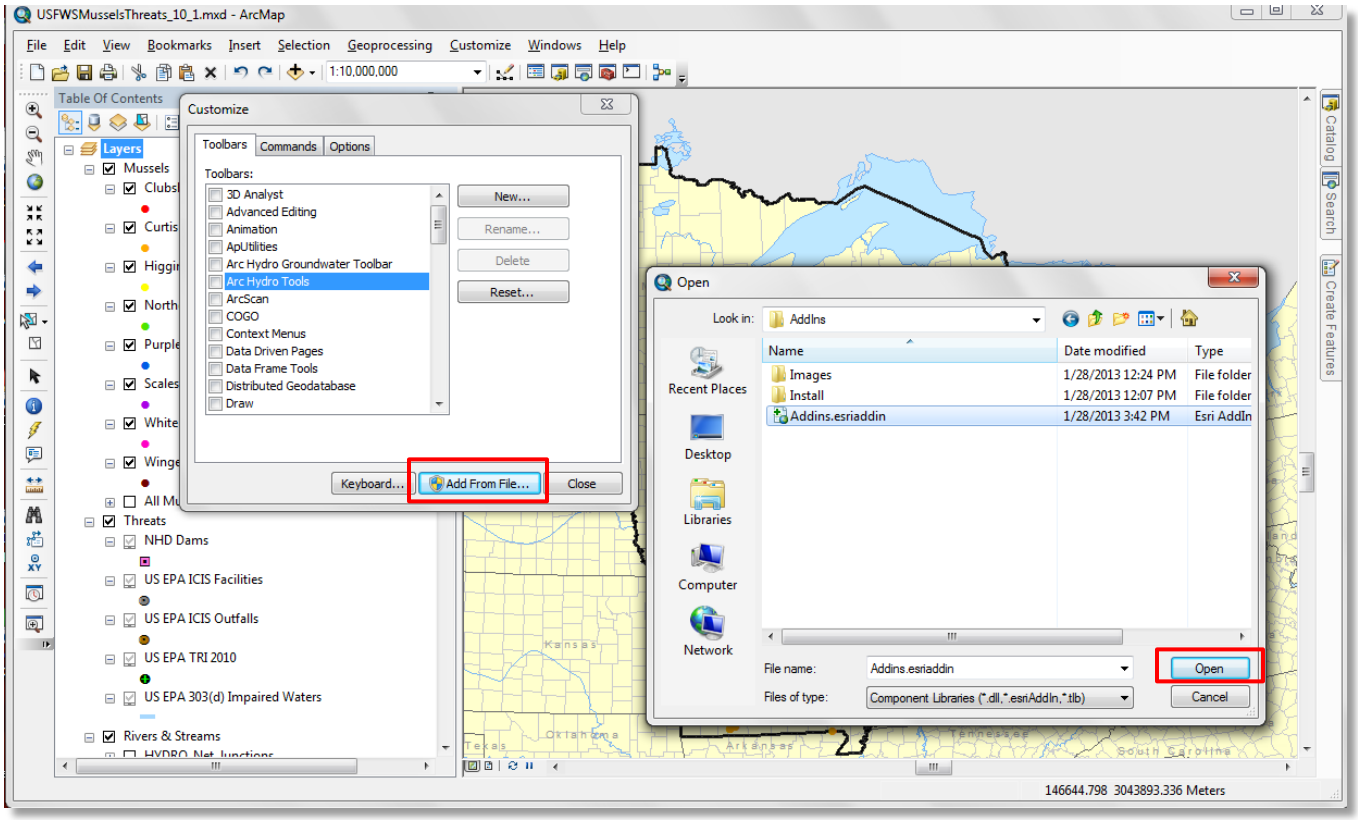

Figure 5. Selecting the USFWS Mussel Tool Add-In file

Click on **Install Add-In** button to properly install the USFWS Mussel Threats Tool (Figure 6).

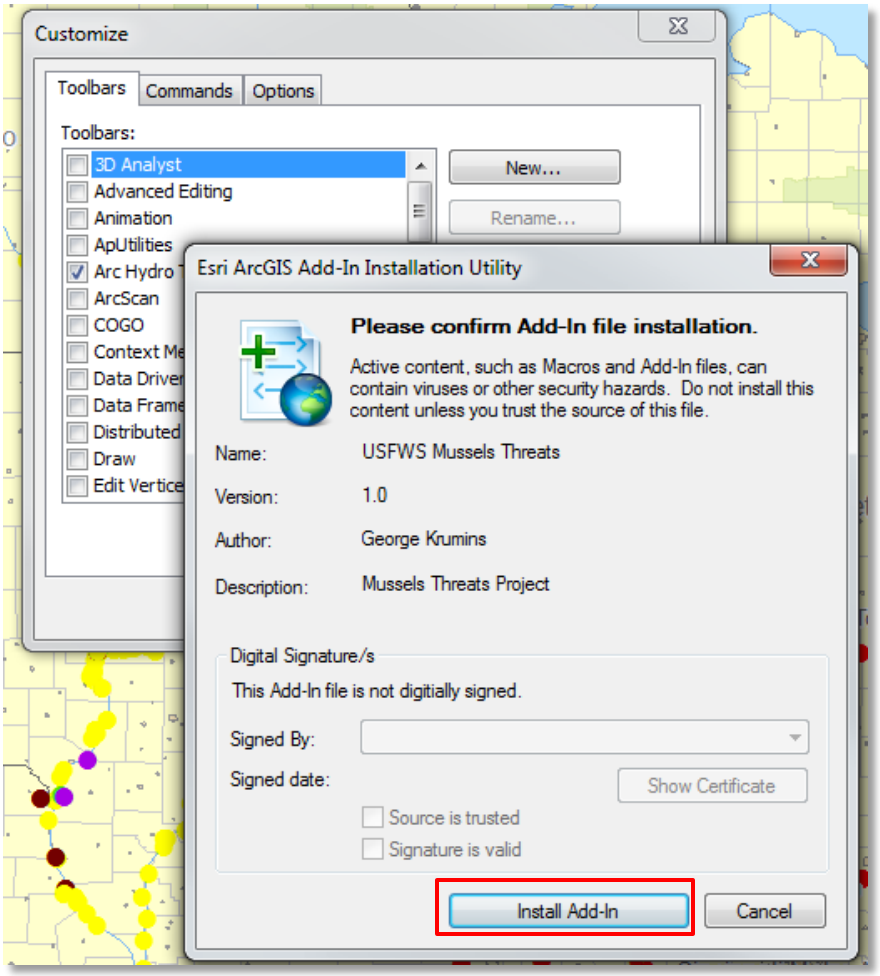

Figure 6. ESRI ArcGIS Add-In Installation Utility

Once the tool is installed a dialog box with a list of Added Objects will appear. Click **OK** (Figure 7).

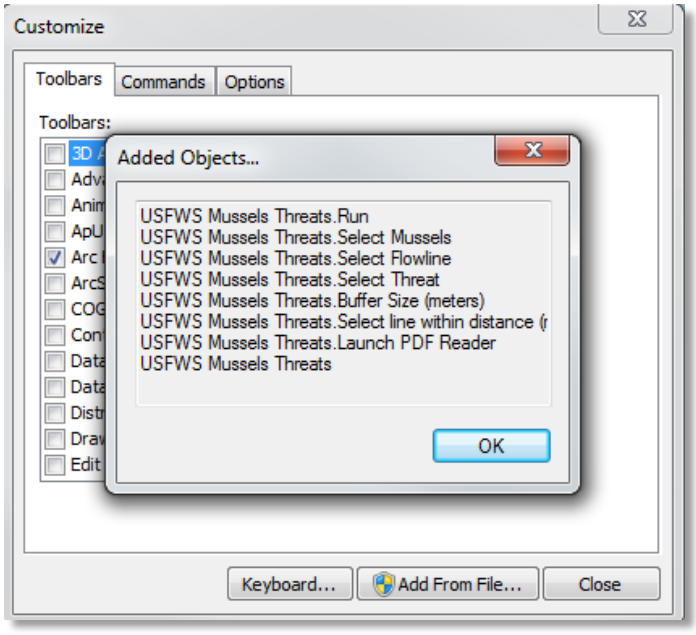

Figure 7. Objects added as part of the USFWS Mussel Threat Tool

USFWS Mussel Threats should now show up under the list of available Toolbars. Check the box next to the USFWS Mussels Threats to turn on the toolbar. Then click **Close** (Figure 8).

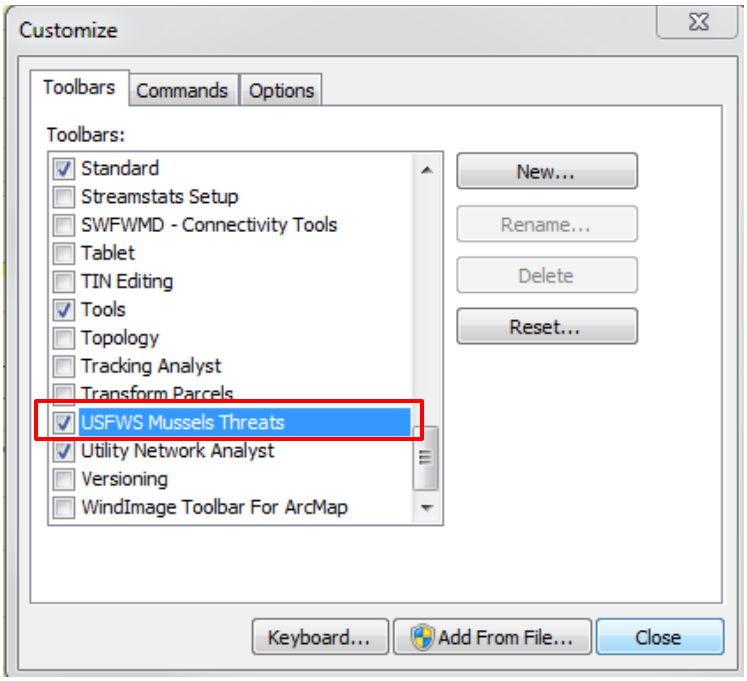

Figure 8. USFWS Mussel Threats Tool

Using the USFWS Mussel Tool in ArcMap

If the USWFWS toolbar is already installed but not turned on, the user should right-click on an empty spot in the toolbar area, selecting the USFWS Mussels Threats tool (See Figure 9). The Utility Network Analyst, Hydrography Event Management Tool, and Arc Hydro Tools should also be selected and then each toolbar can be docked to the top of the screen by moving them to the top (Figure 10).

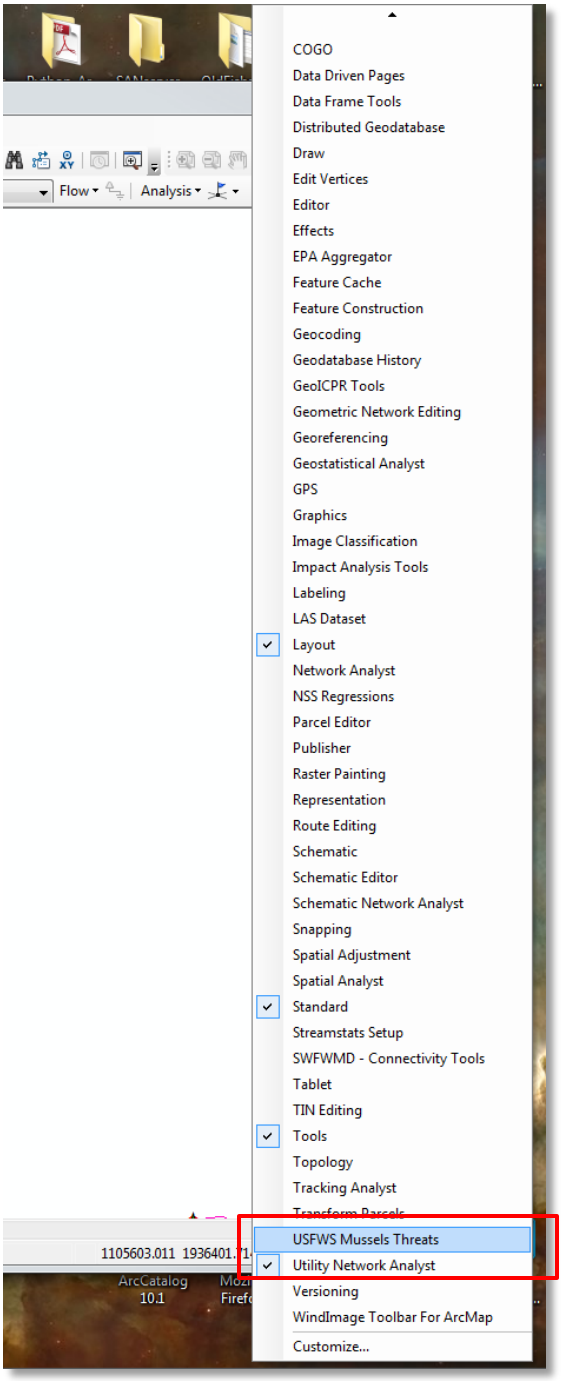

Figure 9. Turning on Toolbars in ArcMap

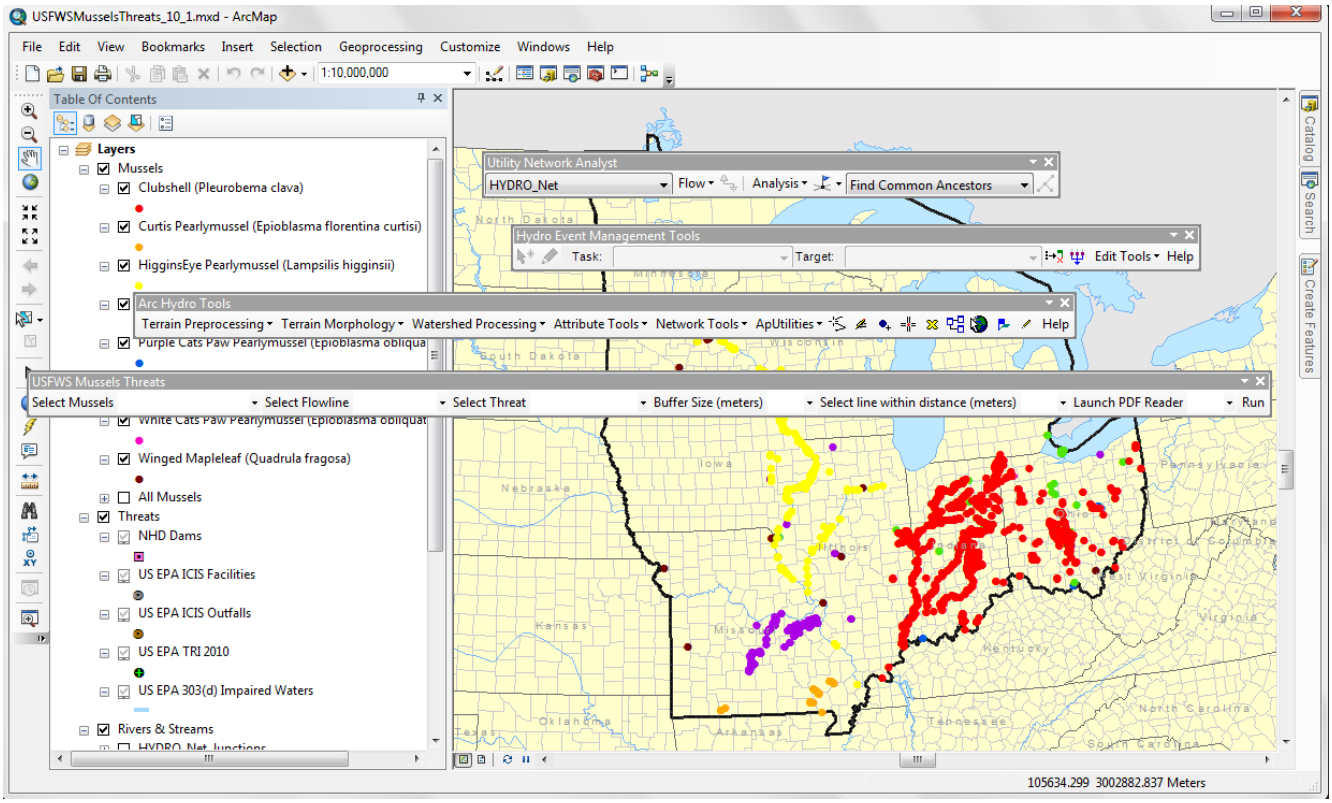

Figure 10. Utility Network Analyst, Hydro Event Management Tools, Arc Hydro Tools, and the USFWS Mussel Threats Toolbars turned on in ArcMap.

Below are the basic steps to use the Mussels Threats tool:

1. The user selects layers and other selections from the dropdown lists in the Mussels Threats toolbar. These selections are processed by the Python script.

2. The NHDFlowline stream segments which intersect the selected mussel points' layer are buffered and a polygon layer is created for this buffer and then intersected with a selected threats layer. This buffer layer is added to the Output group in the ArcMap Table of Contents (TOC).

3. A report in PDF file format is created from the selected point records, and displayed as formatted tables, with one record for each point.

4. The newly created layer is added to the TOC and therefore the map. Duplicate names are not allowed; if a duplicated name is chosen, the new shapefile and report will replace the old shapefile and report. The user has the ability to rename the output layer in the process.

There are a total of six selections needed to run the tool. Start by selecting a mussel species already listed in the TOC, for example the White Cat's Paw Pearly Mussel, which contains 74 locations in Indiana and Ohio. The user can also highlight a few mussel points of interest in a specific area, then right click and select Data -- Export Data and save these records as a shapefile in any location. When

asked if you want to add the exported data to the map as a layer, select yes. This new layer is added to the top of the TOC and in order to be able to select this layer from the Select Mussels pulldown list the user will need to move the layer so that it appears in the Mussels Group layer. Second, select the NHDFlowline layer. Third, select a threats layer, for example US EPA 303(d) Impaired Waters. Fourth, select a buffer distance in meters, for example 100. This is the distance the NHDFlowline streams that intersect the mussel points will be buffered. Fifth, select a line distance in meters for which additional streams than those already selected in the fourth step will be selected and buffered, for example 1500. Finally, select yes or no to launch the PDF reader after the tool is run. A default program must be associated to open PDF report files automatically; typically this is Adobe Acrobat Reader, but nearly any application which opens PDF files will work. The default option on the Mussels Threats toolbar is set to 'No' but if 'Yes' is selected the Mussels Threats tool will open the PDF report automatically. This PDF report contains the formatted tabular records which correspond to the threats points selected geographically by the tool, with one record shown per point. After all the selections are made, click the **Run** button and the script is launched using the selected values (Figure 11).

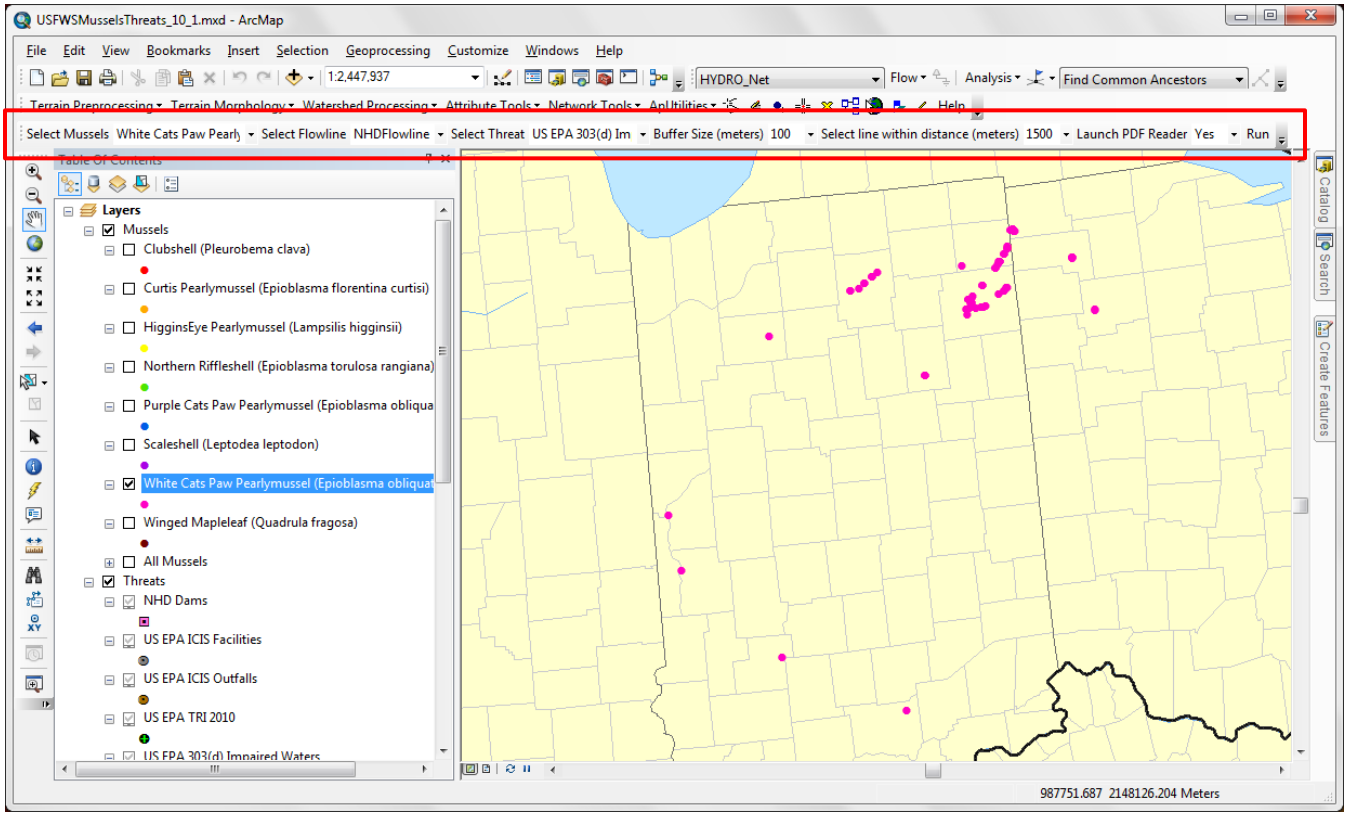

Figure 11. Mussel Threats Tool with the following options selected: White Cat's Paw Pearly Mussel, NHDFlowline, US EPA 303(d) Impaired Waters, Buffer size = 100, line distance = 1500, and Yes to launch the PDF reader.

After running for a brief time, the first dialog box will pop up allowing the user a choice of where to save the output shapefile. Selecting 'Yes' will save the shapefile in the directory defined by the environment variable MUSSELSTHREATS plus the string "ThreatsOutput," for example, if MUSSELSTHREATS is set to C:\MusselsThreats then the default location for the shapefile will be "C:\MusselsThreats\ThreatsOutput." If 'No' is selected, a dialog box will open, and the user can browse to any directory which has write access. For this example, select **Yes** (Figure 12).

NOTE: Do not use the slash instead of the backslash, i.e. do not use 'C:/MusselsThreats' as the tool will not work using the slash.

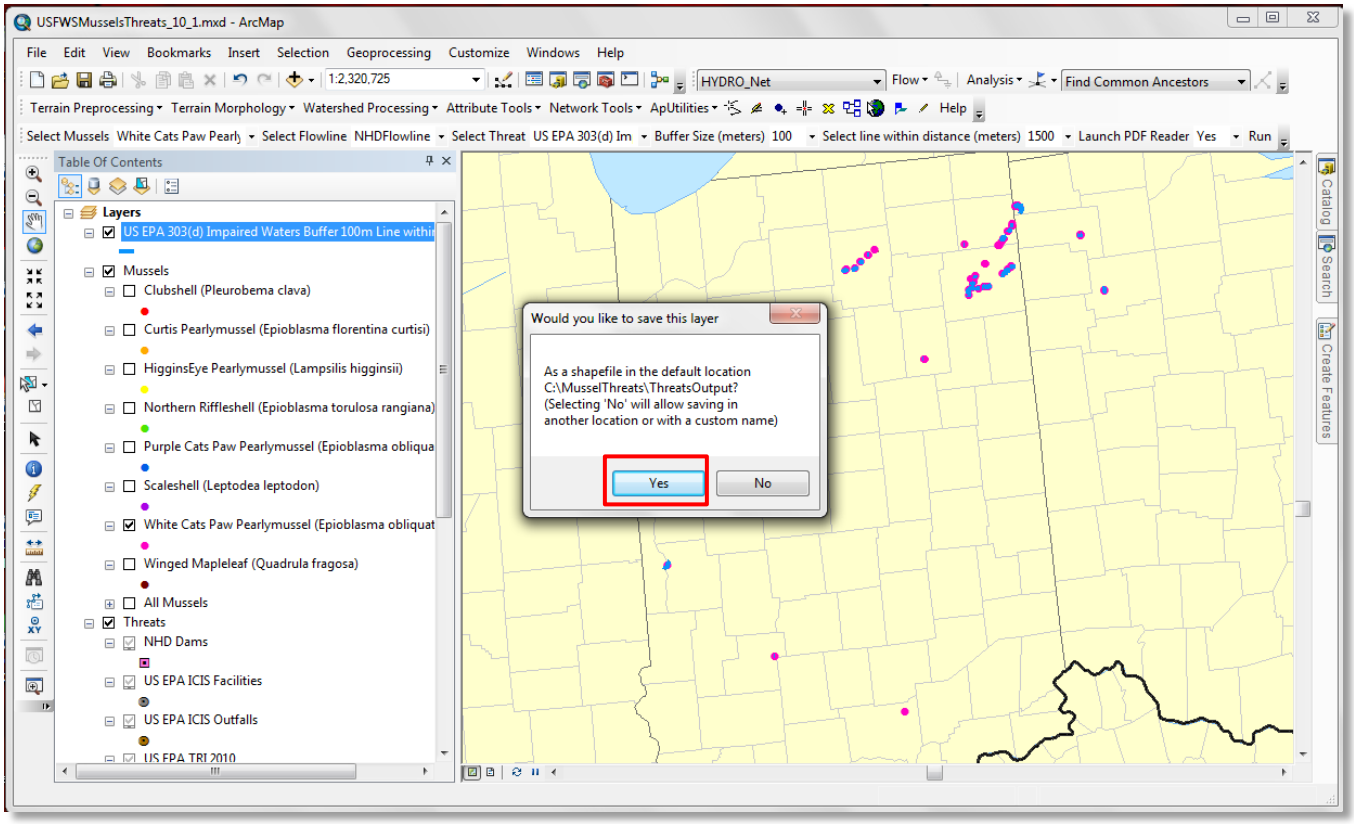
USFWSMusselsThreats_10_1.mxd - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
Table Of Contents
Layers
US EPA 303(d) Impaired Waters Buffer 100m Line
Mussels
Clubshell (Pleurobema clava)
Curtis Pearlymussel (Epioblasma florentina curtisi)
HigginsEye Pearlymussel (Lampsilis higginsii)
Northern Riffleshell (Epioblasma torulosa rangiana)
Purple Cats Paw Pearlymussel (Epioblasma obliqua
Scaleshell (Leptodea leptodon)
White Cats Paw Pearlymussel (Epioblasma obliquat
Winged Mapleleaf (Quadrula fragosa)
All Mussels
Threats
NHD Dams
US EPA ICIS Facilities
US EPA ICIS Outfalls
Would you like to save this layer
As a shapefile in the default location C:\MusselThreats\ThreatsOutput? (Selecting 'No' will allow saving in another location or with a custom name)
Yes
No

Figure 12. Pop up allowing the user a choice of where to save the output shapefile.

The next dialog box will pop up and indicate the location where the shapefile is saved. In this example, the location is the default location which is C:\MusselThreats\ThreatsOutput (Figure 13). If "No" was selected the location of where the user saved the shapefile will be identified here.

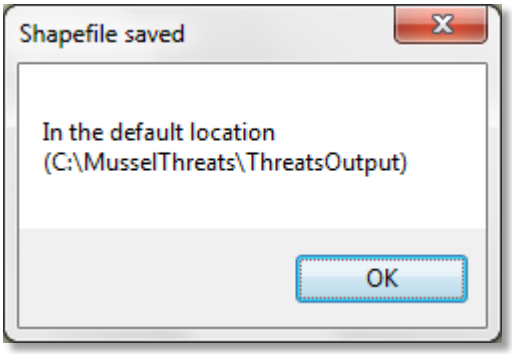

Figure 13. Verification indicating the saved location of output shapefile

The phyton script will run and the final output shapefile will be added to the TOC and symbolized according to the current symbology of the selected threat layer and the PDF report of records in the

selected threat layer will be opened (Figure 14). The PDF report files are saved in the same location as the newly created shapefiles and are available to open at any time.

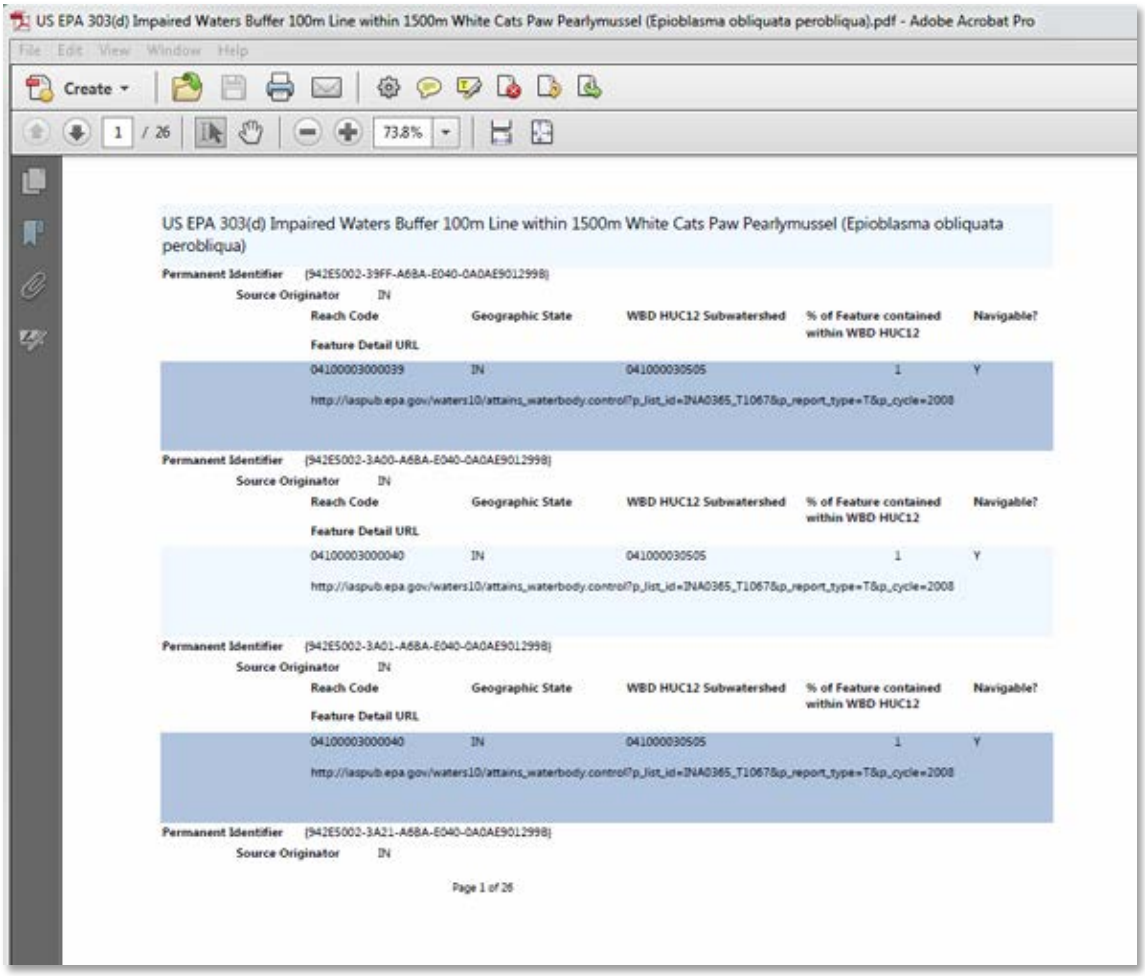
US EPA 303(d) Impaired Waters Buffer 100m Line within 1500m White Cats Paw Pearlymussel (Epioblasma obliquata perobliqua).pdf - Adobe Acrobat Pro
US EPA 303(d) Impaired Waters Buffer 100m Line within 1500m White Cats Paw Pearlymussel (Epioblasma obliquata perobliqua)
Permanent Identifier
Source Originator
Reach Code
Geographic State
WBD HUC12 Subwatershed
% of Feature contained within WBD HUC12
Navigable?
Feature Detail URL
Page 1 of 26

Figure 14. US EPA 303(d) Impaired Water PDF report for White Cat's Paw Pearlymussel

A dialog box indicating that the process was successfully completed will also appear (Figure 15).

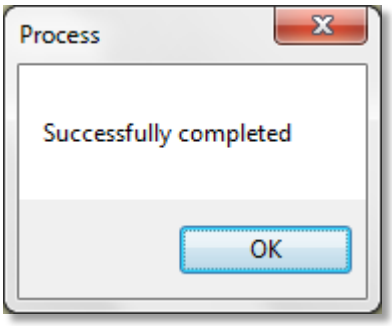

Figure 15. Verification that process was successfully completed

Since the Python script creates the dropdown lists by TOC group and matching names (as partial character strings), to correctly find the mussels layers for selection the mussel layers must be contained

in the TOC within the Mussels group, the threats if they are in the Threats group, and the NHDFlowline layer if they are in the Rivers & Streams group.

These rules exist to prevent incorrect selections. For example, if the layer for the Clubshell mussels is added to the TOC from the geodatabase, the name of the layer would be, by default, "Clubshell_SnappedToNHDFlowline." If the user adds the layer to the correct group, that is, the Mussels group, when selecting from the dropdown boxes this layer is only available in the correct "Select Mussels" list.

Using the Utility Network Analyst and the Hydrography Event Management Tool

Another method is to use the Utility Network Analyst tool to select the interested NHDFlowlines instead of selecting a mussel point layer and then run the tool and report on these selected NHDFlowlines. All the dropdown boxes in the USFWS Mussel Threats tool must still be selected, even though the selection for the mussel's layer is not used in this case, because the script will not run with blank choices. If there are more than 500 NHDFlowline features selected a dialog box appears with an error message stating that the tool will not run, and the box will also show how many features are selected. Clicking **OK** will dismiss the box, remove the selection, and the user should try again with selecting either fewer Flowlines.

Start by selecting the **Analysis** dropdown, select **Options…**, select the **Results** tab, and in the **Results format** pane, select **Selection** instead of **Drawings**. This will ensure that features which are selected using the Utility Network Analyst can be used for the reporting process. The next feature of the toolbar, depicted by the blue flag with an 'X' at its base (see Figure 16) is one of four tools (of the blue and red flag and barrier icons) which can be used to help select NHDFlowline stream segments for reporting.

Four network selection tools are available:

1. Add Junction Flag Tool– this flag marks the start of a navigation path at a junction
2. Add Edge Flag Tool – this flag marks the start of a navigation path along an edge
3. Add Junction Barrier Tool–this flag marks the end of a navigation path at a junction
4. Add Edge Barrier Tool– this flag marks the end of a navigation path along an edge

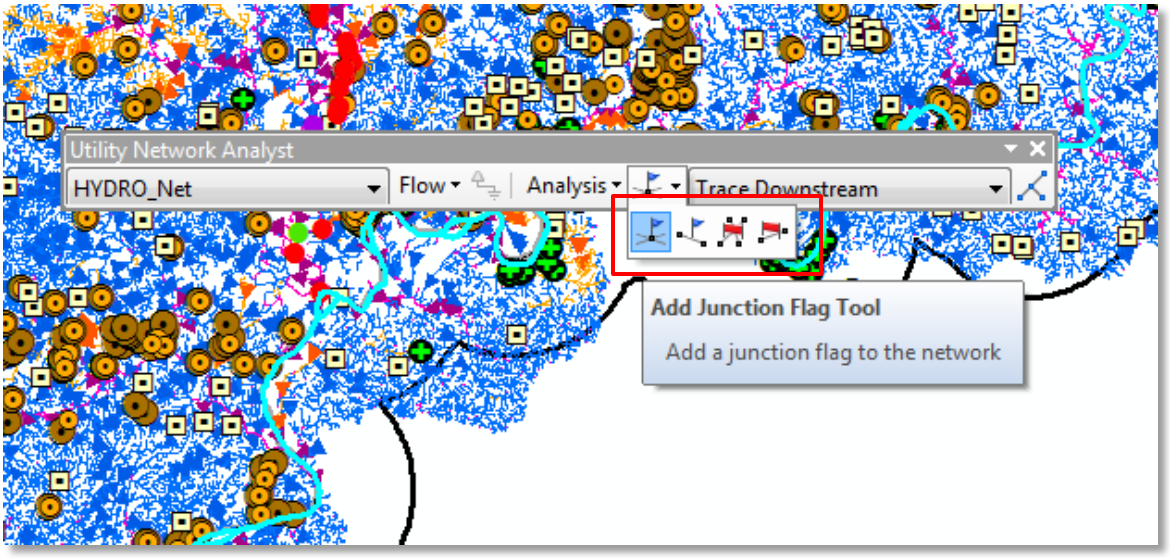

Figure 16. Choosing the Flag or Barrier to select network features

The **HYDRO_Net_Junctions** point layer in the **Rivers & Steams** group shows the locations of the junctions, and can be used for the **Junction Flag Tool** and **Junction Barrier Tool**. The **Edge** tools can be placed anywhere along the NHDFlowline. Note that since the minimum visible scale range for the NHDFlowline layer is set to 1:200,000, it may be necessary to reset the minimum scale to show all the selected features, as in the example shown in Figure 16.

To add an **Add Barrier Flag Tool**, select the blue flag (with the 'X' at the base of the icon) and click a point view belonging to the **HYDRO_Net_Junctions** layer. If **Trace Downstream** is selected in the next dropdown list and the **Solve** button ( ) is clicked, the downstream segment will be selected. This segment can be quite lengthy. If a barrier is placed downstream, the selected segment(s) will stop at that barrier, as seen in Figure 17. Specifically, the flag starts with a selection of the **Flowline** segment it intersects, and for the barrier the segment selections stops on the previous line segment. Notice that the **Edge Barrier Tool** marker is somewhat hard to see, since the marker is a thin red 'X.' The appearance of this marker cannot be changed. In this figure, the **Display Arrows** has been selected from the **Flow** dropdown list.

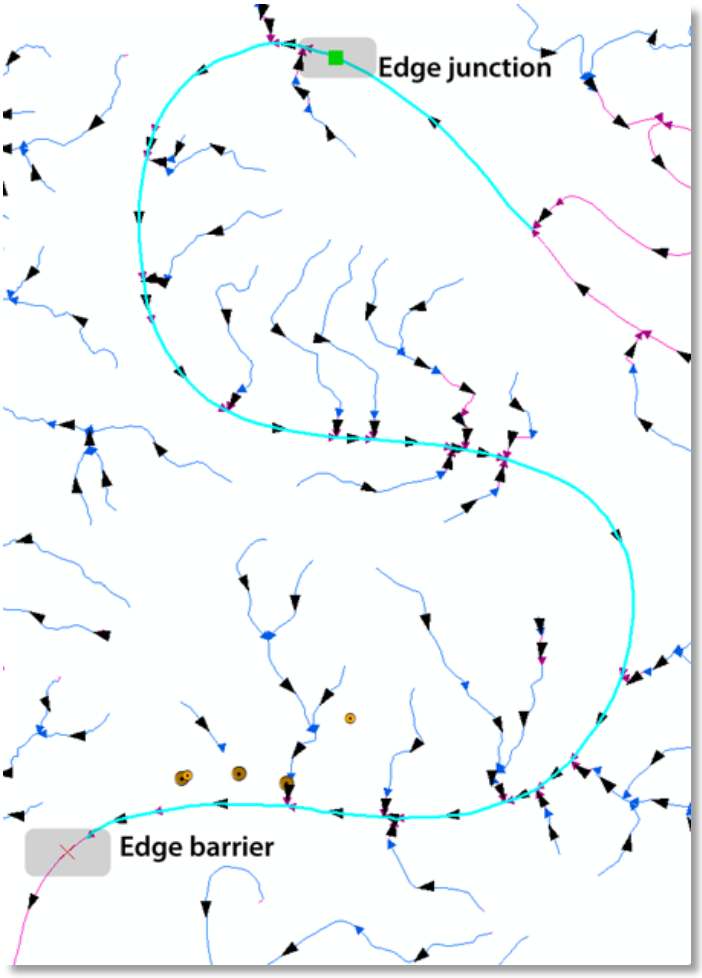

Figure 17. Flowline selection using Trace Downstream from Edge Flag to Edge Barrier

To clear the flags and barriers select **Clear Flags** or **Clear Barriers** from the **Analysis** dropdown list (Figure 18).

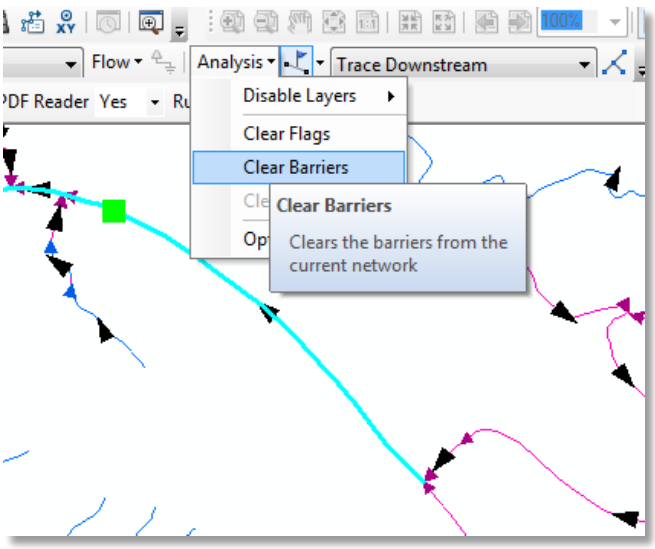

Figure 18. Use the Analysis dropdown list to clear flags and barriers

The user can also select certain mussel locations and then use the Hydrography Event Management Tool to set those selected locations as flags. For example, zoom to the North Folk of the Vermillion River in Vermilion County, IL then right click on the Clubshell mussel layer and select **Selection – Make this the only Selectable Layer.** Use the selection button to select the Clubshell points in this area (Figure 19).

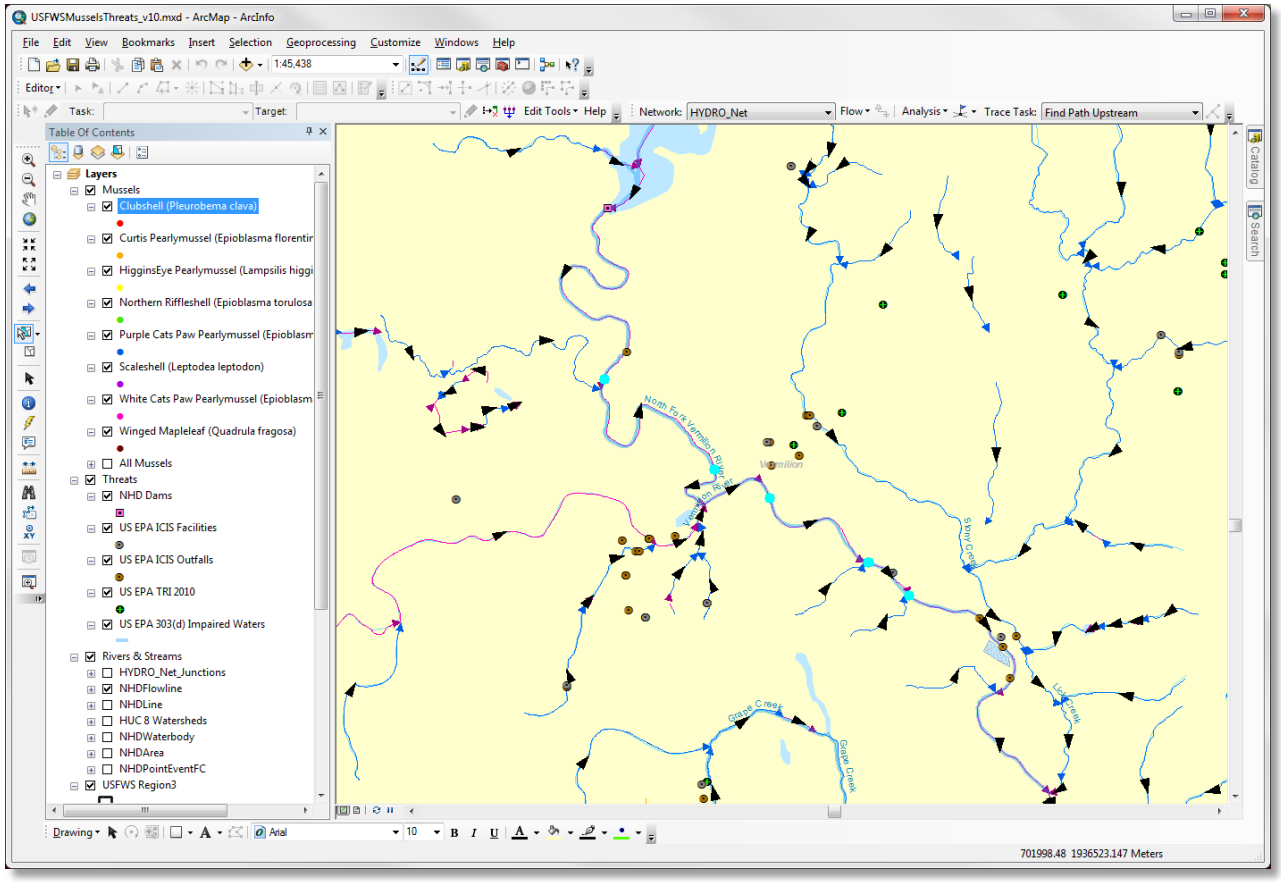

Figure 19 . Clubshell mussel locations selected along the North Folk of the Vermillion River in Vermilion County, IL

On the HEM toolbar, select the convert points to flags/barriers icon (Figure 20).

Figure 20. Convert Points to Flags/Barriers icon

Select **Flags** and then click **OK** (Figure 21).

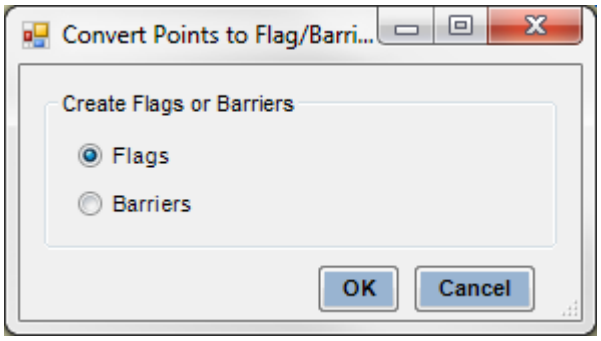

Figure 21. Convert Points to Flags/Barriers Dialog Box

The mussel locations are converted to flags and are indicated as such with big green squares. Now, using the Utility Network Analyst tool the user can select one of the Trace Tasks, for example **Find Path Upstream,** and click **Solve** to select NHDFlowlines (Figure 22).

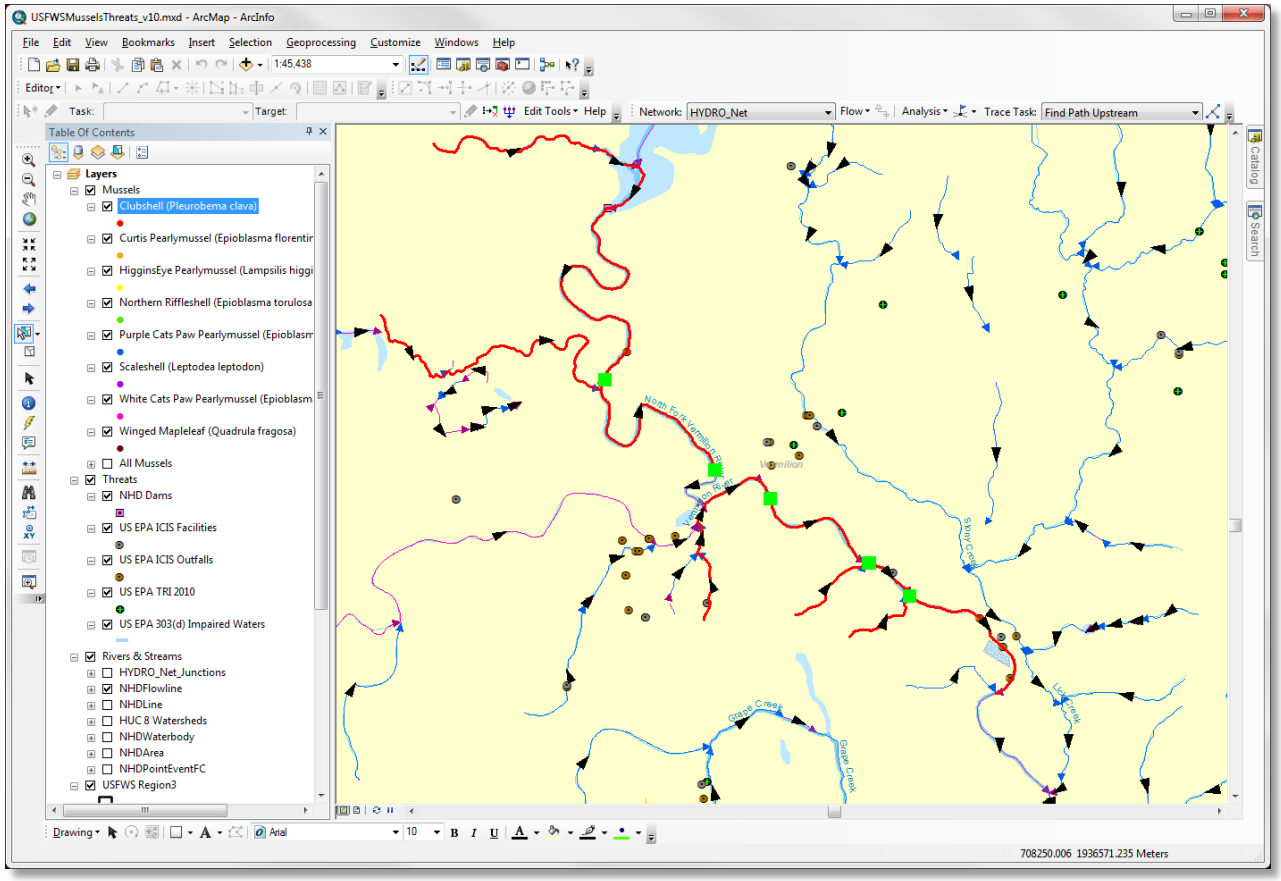

Figure 22. Selected upstream NHDFlowlines from the Clubshell mussel locations

The USWS Mussel Threats tool can then be run and report generated, once all the dropboxes are filled in. Remember, if there are more than 500 NHDFlowline features selected a dialog box appears with an error message stating that the tool will not run, and the box will also show how many features are selected. Clicking **OK** will dismiss the box, remove the selection, and the user should try again with selecting either fewer Flowlines.

Figure 23 shows the list of the nine possible options available in the Netweork Utility Analyst. When using placed flags and/or barriers some trace options may not be available. Help for the Network Utility Analyst can be found online at http://resources.arcgis.com/en/help/main/10.1/index.html#//002r00000028000000.

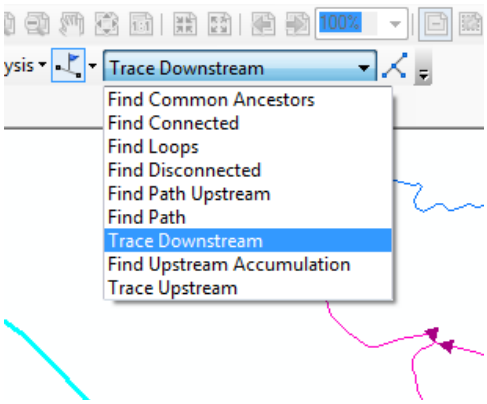

Figure 23. List of Find and Trace options